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Nanoconjugates of a calixresorcinarene derivative with methoxy poly(ethylene glycol) fragments for drug encapsulation

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Abstract

© 2018 Ermakova et al. In order to obtain a non-toxic amphiphilic calixresorcinarene capable to form nanoconjugates for drug encapsulation, tetraundecylcalixresorcinarene functionalized by methoxy poly(ethylene glycol) chains has been synthesized. The macrocycle obtained is characterized by low hemotoxicity. In aqueous solution it forms nanoassociates that are able to encapsulate organic substrates of different hydrophobicity, including drugs (doxorubicin, naproxen, ibuprofen, quercetin). The micelles of the macrocycle slowed down the release of the hydrophilic substrates in vitro. In physiological sodium chloride solution and phosphate-buffered saline, the micelles of the macrocycle acquire thermoresponsive properties and exhibit a temperature-controlled release of doxorubicin in vitro. The combination of the low toxicity and the encapsulation properties of the obtained calixresorcinarene-mPEG conjugate shows promising potential for the use as a supramolecular drug-delivery system.

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Keywords

Calixresorcinarene, Drug encapsulation, Hemotoxicity, Methoxy poly(ethylene glycol), Temperature-controlled release

References

[1] Kaur, P.; Garg, T.; Rath, G.; Murthy, R. S. R.; Goyal, A. K. Drug Delivery 2016, 23, 727-738. doi:10.3109/10717544.2014.935530

[2] Allen, T. M.; Cullis, P. R. Adv. Drug Delivery Rev. 2013, 65, 36-48. doi:10.1016/j.addr.2012.09.037

[3] Martin, C.; Aibani, N.; Callan, J. F.; Callan, B. Ther. Delivery 2016, 7, 15-31. doi:10.4155/tde.15.84

[4] Webber, M. J.; Langer, R. Chem. Soc. Rev. 2017, 46, 6600-6620. doi:10.1039/c7cs00391a

[5] Gutshe, C. D. Calixarenes: an Introduction, 2nd ed.; Royal Society of Chemistry: Cambridge, United Kingdom, 2008. doi:10.1039/9781847558190

[6] Morozova, J. E.; Syakaev, V. V.; Kazakova, E. K.; Shalaeva, Y. V.; Nizameev, I. R.; Kadirov, M. K.; Voloshina, A. D.; Zobov, V. V.; Konovalov, A. I. Soft Matter 2016, 12, 5590-5599. doi:10.1039/c6sm00719h

[7] Mironova, D. A.; Muslinkina, L. A.; Syakaev, V. V.; Morozova, J. E.; Yanilkin, V. V.; Konovalov, A. I.; Kazakova, E. K. J. Colloid Interface Sci. 2013, 407, 148-154. doi:10.1016/j.jcis.2013.06.048

[8] Syakaev, V. V.; Kazakova, E. K.; Morozova, J. E.; Shalaeva, Y. V.; Latypov, S. K.; Konovalov, A. I. J. Colloid Interface Sci. 2012, 370, 19-26. doi:10.1016/j.jcis.2011.12.069

[9] Kazakova, E.; Morozova, J.; Mironova, D.; Syakaev, V.; Muslinkina, L.; Konovalov, A. Supramol. Chem. 2013, 25, 831-841. doi:10.1080/10610278.2013.809085

[10] Gorbatchuk, V. V.; Porreva, A. V.; Stepanova, V. B.; Kuzin, Yu. I.; Evtugyn, V. G.; Shamagsumova, R. V.; Stoikov, I. I.; Evtugyn, G. A. Sens. Actuators, B 2017, 246, 136-145. doi:10.1016/j.snb.2017.02.061

[11] Gorbachuk, V. V.; Mostovaya, O. A.; Evtugyn, V. G.; Osin, Y. N.; Rizvanov, I. K.; Gerasimov, A. V.; Stoikov, I. I. Macroheterocycles 2017, 10, 174-181. doi:10.6060/mhc170513s

[12] Tu, C.; Zhu, L.; Li, P.; Chen, Y.; Su, Y.; Yan, D.; Zhu, X.; Zhou, G. Chem. Commun. 2011, 47, 6063-6065. doi:10.1039/c0cc05662f

[13] Yoshida, K.; Fujii, S.; Takahashi, R.; Matsumoto, S.; Sakurai, K. Langmuir 2017, 33, 9122-9128. doi:10.1021/acs.langmuir.7b02196

[14] Valkenier, H.; Malytskyi, V.; Blond, P.; Retout, M.; Mattiuzzi, A.; Goole, J.; Raussens, V.; Jabin, I.; Bruylants, G. Langmuir 2017, 33, 8253-8259. doi:10.1021/acs.langmuir.7b02140

[15] Mustafina, A.; Zakharova, L.; Elistratova, J.; Kudryashova, J.; Soloveva, S.; Garusov, A.; Antipin, I.; Konovalov, A. J. Colloid Interface Sci. 2010, 346, 405-413. doi:10.1016/j.jcis.2010.03.002

[16] Ten'kovstev, A. V.; Razina, A. B.; Dudkina, M. M. Polym. Sci., Ser. B 2014, 56, 274-281. doi:10.1134/s1560090414030166

[17] Drakalska, E.; Momekova, D.; Manolova, Y.; Budurova, D.; Momekov, G.; Genova, M.; Antonov, L.; Lambov, N.; Rangelov, S. Int. J. Pharm. 2014, 472, 165-174. doi:10.1016/j.ijpharm.2014.06.034

[18] Momekova, D.; Budurova, D.; Drakalska, E.; Shenkov, S.; Momekov, G.; Trzebicka, B.; Lambov, N.; Tashev, E.; Rangelov, S. Int. J. Pharm. 2012, 436, 410-417. doi:10.1016/j.ijpharm.2012.06.053

[19] Dria, R. D.; Goudy, B. A.; Moga, K. A.; Corbin, P. S. Polym. Chem. 2012, 3, 2070-2081. doi:10.1039/c2py20188g

[20] Wu, R.; Al-Azemi, T. F.; Bisht, K. S. RSC Adv. 2014, 4, 16864-16870. doi:10.1039/c3ra47678b

[21] Gou, P.-F.; Zhu, W.-P.; Shen, Z.-Q. J. Polym. Sci., Part A: Polym. Chem. 2008, 46, 2108-2118. doi:10.1002/pola.22545

[22] Gao, C.; Wang, Y.; Zhu, W.-p.; Shen, Z.-q. Chin. J. Polym. Sci. 2014, 32, 1431-1441. doi:10.1007/s10118-01--1528-4

[23] Mishra, P.; Nayak, B.; Dey, R. Asian J. Pharm. Sci. 2016, 11, 337-348. doi:10.1016/j.ajps.2015.08.011

[24] Knop, K.; Hoogenboom, R.; Fischer, D.; Schubert, U. S. Angew. Chem., Int. Ed. 2010, 49, 6288-6308. doi:10.1002/anie.200902672

[25] Guinier, A.; Fournet, G. Small-angle Scattering of X-rays; Wiley: New York, NY, U.S.A., 1955

[26] Konarev, P. V.; Volkov, V. V.; Sokolova, A. V.; Koch, M. H. J.; Svergun, D. I. J. Appl. Crystallogr. 2003, 36, 1277-1282. doi:10.1107/S0021889803012779

[27] Svergun, D. I.; Ekström, F.; Vandegriff, K. D.; Malavalli, A.; Baker, D. A.; Nilsson, C.; Winslow, R. M. Biophys. J. 2008, 94, 173-181. doi:10.1529/biophysj.107.114314

[28] Svergun, D. I. J. Appl. Crystallogr. 1992, 25, 495-503. doi:10.1107/S0021889892001663

[29] Bondi, A. J. Phys. Chem. 1964, 68, 441-451. doi:10.1021/j100785a001

[30] Zhao, Y. H.; Abraham, M. H.; Zissimos, A. M. J. Org. Chem. 2003, 68, 7368-7373. doi:10.1021/jo034808o

[31] Hong, H.; Mai, Y.; Zhou, Y.; Yan, D.; Cui, J. Macromol. Rapid Commun. 2007, 28, 591-596. doi:10.1002/marc.200600752

[32] Fang, Y.; Giesecke, M.; Furó, I. J. Phys. Chem. B 2017, 121, 2179-2188. doi:10.1021/acs.jpcb.6b12381

[33] Mohsen-Nia, M.; Rasa, H.; Modarress, H. J. Chem. Eng. Data 2006, 51, 1316-1320. doi:10.1021/je060061y

[34] Tetko, I. V.; Gasteiger, J.; Todeschini, R.; Mauri, A.; Livingstone, D.; Ertl, P.; Palyulin, V. A.; Radchenko, E. V.; Zefirov, N. S.; Makarenko, A. S.; Tanchuk, V. Y.; Prokopenko, V. V. J. Comput.-Aided Mol. Des. 2005, 19, 453-463. doi:10.1007/s10822-005-8694-y

[35] Buchweitz, M.; Kroon, P. A.; Rich, G. T.; Wilde, P. J. Food Chem. 2016, 211, 356-364. doi:10.1016/j.foodchem.2016.05.034

[36] Tunstad, L. M.; Tucker, J. A.; Dalcanale, E.; Weiser, J.; Bryant, J. A.; Sherman, J. C.; Helgeson, R. C.; Knobler, C. B.; Cram, D. J. J. Org. Chem. 1989, 54, 1305-1312. doi:10.1021/jo00267a015

[37] Shuai, X.; Ai, H.; Nasongkla, N.; Kim, S.; Gao, J. J. Controlled Release 2004, 98, 415-426

[38] He, Y.; He, W.; Liu, D.; Gu, T.; Wei, R.; Wang, X. Polym. Chem. 2013, 4, 402-406. doi:10.1039/c2py20653f

[39] Voloshina, A. D.; Semenov, V. E.; Strobykina, A. S.; Kulik, N. V.; Krylova, E. S.; Zobov, V. V.; Reznik, V. S. Russ. J. Bioorg. Chem. 2017, 43, 170-176. doi:10.1134/S1068162017020170

[40] Small Angle X-ray Scattering. Version 4.0. Software Reference Manual, M86-E00005-0600, Bruker AXS Inc., 2000

[41] SasView for Small Angle Scattering Analysis. https://www.sasview.org/index.html (accessed July 1, 2018)

[42] Chen, X.; Ahn, D. U. J. Am. Oil Chem. Soc. 1998, 75. doi:10.1007/s11746-998-0322-2

[43] Swarbrick, J.; Galownia, J.; Bates, T. R. J. Colloid Interface Sci. 1972, 41, 609-611. doi:10.1016/0021-9797(72)90385-2

[44] Stepankova, J.; Studenovsky, M.; Malina, J.; Kasparkova, J.; Liskova, B.; Novakova, O.; Ulbrich, K.; Brabec, V. Biochem. Pharmacol. 2011, 82, 227-235. doi:10.1016/j.bcp.2011.04.010

[45] Mchedlov-Petrosyan, N. O.; Kholin, Y. V. Russ. J. Appl. Chem. 2004, 77, 414-422. doi:10.1023/B:RJAC.0000031281.69081.d0